

COMMUNITY STRUCTURE OF AMPHIBIANS AT THREE PROTECTED AREAS OF KERALA¹

M.I. ANDREWS^{2,4}, SANIL GEORGE³ AND JAIMON JOSEPH²

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²Department of Zoology, Mar Thoma College, Tiruvalla 689 103, Kerala, India.

³Rajiv Gandhi Centre for Biotechnology, Trivandrum 695 014, Kerala, India. Email: rhacophorus@rediffmail.com

⁴Email: mipeandrews@yahoo.co.in

The community structure of amphibian assemblages in three protected areas of Kerala – Peppara Wildlife Sanctuary, Periyar Tiger Reserve and Agasthyavanam Biological Park – has been studied. Population census, diversity, evenness, richness, ecological distribution, niche breadth and niche overlap of amphibians were determined. There was high species diversity at all the sites. More than one female was available for each male of all the species. The amphibian community was evenly distributed at each area. Niche breadth was high in Agasthyavanam Biological Park, followed by Periyar Tiger Reserve and Peppara Wildlife Sanctuary. Niche overlap values indicate that the amphibian communities in the three protected areas show great ecological similarity among sympatric species.

Key words: Amphibians, community structure, protected areas, Kerala

INTRODUCTION

Amphibians, particularly frogs and toads, in many widely separated parts of the world appear to be declining (Barinaga 1990; Wake 1991). The most predominant factor responsible for the decline is anthropogenic activities, which result in shrinkage of habitats where amphibians are found. Several studies have been made on amphibian communities in different ecosystems. Niche overlap and interspecific competition in three species of *Rana* in Sarawak have been reported by Inger and Greenberg (1966). Inger (1969) also studied the organisation of communities of frogs in lowland streams in Sarawak. Crump (1971) made a quantitative analysis of ecological distribution of tropical herpetofauna. Densities of floor dwelling frogs in lowland forests of southeast Asia and Central America have been studied by Inger (1980). Inger and Voris (1993) made a comparative study on the Bornean amphibian communities. Resource utilisation by the amphibian community in Borneo has been reported by Das (1996a). Similar studies are few in India (Inger *et al.* 1987; Dash and Mahanta 1993; Das 1996b; Vasudevan *et al.* 2001).

Recently, importance is being given to the conservation of amphibians and to the study of environmental resource utilisation by different species. Kerala has a diverse amphibian fauna (Andrews and George 1998). However, there is little data on the amphibian community's function, which is important for conservation (Inger *et al.* 1987; Dash and Mahanta 1993). The present study was designed to analyse the community structure of amphibians in three protected areas in the Kerala part of the Western Ghats.

MATERIAL AND METHODS

Studies on the community structure of amphibian assemblages at Peppara Wildlife Sanctuary (moist deciduous forest), Periyar Tiger Reserve (semi-evergreen forest) and Agasthyavanam Biological Park (evergreen forest) have been carried out from 2000-2001. Each study site was divided into quadrats of dimensions 50 m x 50 m. The quadrats were demarcated on the selected forest floor and searched thoroughly in such a way that the escape of amphibians from the area was impeded. At all sites, the search for amphibians was done from one end to another of each quadrat at a stretch. Logs were shifted and examined thoroughly, rocks overturned, litter raked and the vegetation examined. Sampling in each quadrat was done for 6 hours daily (0600 to 0900 hrs and 1700-2000 hrs) for two weeks each at Peppara Wildlife Sanctuary (6 quadrats – 3 riparian and 3 non-riparian), Periyar Tiger Reserve (8 quadrats – 3 riparian and 5 non-riparian) and Agasthyavanam Biological Park (3 quadrats – all non-riparian) by two persons using collecting nets and large torches. Frogs/toads captured were identified, measured and released as per the standard methods for amphibians (Heyer *et al.* 1994). Population census, diversity, evenness, richness, ecological distribution, niche breadth and niche overlap of amphibians at all the three sites were studied using the following formulae (Krebs 1999).

1. Simpson's index of diversity:

$$I - D = I - \sum (P_i)^2$$

$I - D$ = Simpson's index of diversity

P_i = Proportion of individuals of species 'i' in the community

2. Shannon-Weiner diversity:

$$H' = \sum_{i=1}^s (P_i) (\log 2 P_i)$$

H' = Index of species diversity

s = Number of species

P_i = Proportion of total sample belonging to i^{th} species

3. Brillouin's diversity:

$$\hat{H} = \frac{1}{N} \log \left(\frac{N!}{n_1! n_2! n_3! \dots} \right)$$

$\hat{H}$ = Brillouin's diversity

N = Total number of individuals in entire collection

$n_1!$ = Number of individuals belonging to species 1

$n_2!$ = Number of individuals belonging to species 2

$n_3!$ = Number of individuals belonging to species 3

4. Smith and Wilson's measure of evenness:

$$E_{\text{var}} = 1 - \left[\frac{2}{\pi \arctan \left\{ \frac{\sum_{i=1}^s \left(\log_e(n_i) - \sum_{j=1}^s \log_e \left(\frac{n_j}{s} \right) \right)^2}{s} \right\}} \right]$$

E_{var} = Smith and Wilson's index of evenness

n_i = Number of individuals in species i in species ($i = 1, 2, 3, \dots$)

n_j = Number of individuals in species j in species ($j = 1, 2, 3, \dots$)

S = Number of species in entire collection

5. Levins's measure of niche breadth:

$$B = \frac{y^2}{\sum N_{j2}}$$

B = Levin's measure of niche breadth

N_j = Number of individuals found in or using resource state j

y = Total number of individuals sampled

6. Jackknife estimate of species richness:

$$S' = s + \left(\frac{n-1}{n} \right) k$$

S' = Jackknife's estimate of species richness

s = Observed total number of species present in n quadrat

n = Total number of quadrat samples

k = Number of unique species

7. Horn's index of niche overlap:

$$R_0 = \frac{\sum (P_{ij} + P_{ik}) \log (P_{ij} + P_{ik}) - \sum P_{ij} \log P_{ij} - \sum P_{ik} \log P_{ik}}{2 \log 2}$$

R_0 = Horn's index

P_{ij} = Proportion resource i is of the total resources utilized by species j

P_{ik} = Proportion resource i is of the total resources utilized by species k

RESULTS AND DISCUSSION

Table 1 provides data on population density of amphibians at three protected areas of Kerala. Of the 17 species of amphibians recorded, 12 species each were recorded from Peppara Wildlife Sanctuary and Periyar Tiger Reserve, while five species were collected from Agasthyavanam Biological Park. Population density of *Rana temporalis* was found to be high in all the three protected areas. At Peppara Wildlife Sanctuary, *Rana temporalis* alone contributed 44% to the total diversity. At Periyar Tiger Reserve and Agasthyavanam Biological Park, *R. temporalis* constituted 40.7 and 41.46% of the total diversity, respectively (Table 2). *Philautus pulcherrimus* and *Rhacophorus malabaricus* were found to be the rarest species in the present study. For all the species, more than one female was available for each male. The sex ratio was maximum in *Rana temporalis* and minimum in *Rhacophorus malabaricus* (Table 3).

The analysis of dominance, diversity and evenness indices provide valuable quantitative information in different

Table 1: Population density of amphibians at three protected areas of Kerala

Sl. No.	Species	Peppara Wildlife Sanctuary	Periyar Tiger Reserve	Agasthyavanam Biological Park
1	<i>Bufo melanostictus</i>	1.5	1.5	0.7
2	<i>Euphlyctis cyanophlyctis</i>	0.5	0.9	-
3	<i>E. hexadactylus</i>	1.5	-	-
4	<i>Limnonectes keralensis</i>	1.7	1.0	2.3
5	<i>L. limnocharis</i>	0.5	2.5	-
6	<i>L. nilagirica</i>	-	0.6	-
7	<i>Rana temporalis</i>	9.2	7.6	4.0
8	<i>Rana curtipes</i>	-	0.4	-
9	<i>Nyctibatrachus major</i>	0.7	0.5	1.7
10	<i>N. minor</i>	0.7	-	-
11	<i>Microhyla ornata</i>	-	0.8	-
12	<i>Micrixalus fuscus</i>	-	0.5	1.0
13	<i>Philautus variabilis</i>	3.5	2.5	-
14	<i>P. pulcherrimus</i>	0.2	-	-
15	<i>Polypedates pseudocruciger</i>	0.8	0.3	-
16	<i>Rhacophorus malabaricus</i>	0.2	-	-

Table 2: Percentage occurrence of amphibians at three protected areas of Kerala

Sl. No.	Species	Peppara Wildlife Sanctuary	Periyar Tiger Reserve	Agasthyavanam Biological Park
1	<i>Bufo melanostictus</i>	7.2	8.0	6.9
2	<i>Euphlyctis cyanophlyctis</i>	2.4	4.7	-
3	<i>E. hexadactylus</i>	7.2	-	-
4	<i>Limnonectes keralensis</i>	8.0	5.3	24.1
5	<i>L. limnocharis</i>	2.4	13.3	-
6	<i>L. nilagirica</i>	-	3.3	-
7	<i>Rana temporalis</i>	44.0	40.7	41.46
8	<i>Rana curtipes</i>	-	2.0	-
9	<i>Nyctibatrachus major</i>	3.2	2.7	17.24
10	<i>N. minor</i>	3.2	-	-
11	<i>Microhyla ornata</i>	-	4.0	-
12	<i>Micrixalus fuscus</i>	-	2.7	10.3
13	<i>Philautus variabilis</i>	16.8	12.0	-
14	<i>P. pulcherrimus</i>	0.8	-	-
15	<i>Polypedates pseudocruciger</i>	4.0	1.3	-
16	<i>Rhacophorus malabaricus</i>	0.8	-	-

Table 3: Male-Female ratio of amphibians at three protected areas of Kerala

Sl. No.	Species	Peppara Wildlife Sanctuary	Periyar Tiger Reserve	Agasthyavanam Biological Park
1	<i>Bufo melanostictus</i>	2.33	1.84	2.11
2	<i>Euphlyctis cyanophlyctis</i>	1.93	1.72	-
3	<i>E. hexadactylus</i>	2.14	-	-
4	<i>Limnonectes keralensis</i>	2.57	1.78	2.25
5	<i>L. limnocharis</i>	2.36	3.22	-
6	<i>L. nilagirica</i>	-	0.16	-
7	<i>Rana temporalis</i>	4.89	5.22	4.92
8	<i>Rana curtipes</i>	-	1.89	-
9	<i>Nyctibatrachus major</i>	1.09	1.39	1.27
10	<i>N. minor</i>	1.18	-	-
11	<i>Microhyla ornata</i>	-	0.52	-
12	<i>Micrixalus fuscus</i>	-	1.29	1.39
13	<i>Philautus variabilis</i>	2.27	2.12	-
14	<i>P. pulcherrimus</i>	0.49	-	-
15	<i>Polypedates pseudocruciger</i>	2.13	1.89	-
16	<i>Rhacophorus malabaricus</i>	0.05	-	-

habitats. For the analysis of dominance, three indices were used in the present study. Simpson's diversity index was found to be 0.763 (Peppara) 0.792 (Periyar) and 0.751

(Agasthyavanam), which indicates a high species diversity in all the protected areas. Shannon-Wiener's diversity does not seem to exceed 5.0 for most of the biological communities. In the present study also, the values are within the limits and show high diversity. Brillouin's index is used when the sampling is done without replacement. It is practically identical to Shannon-Wiener index. In the present study too, diversity was found to be high (Table 4). At Peppara, *Rana temporalis* and *Philautus variabilis* contributed 60.8% of the total diversity index value. At Periyar, *Rana temporalis*, *Limnonectes limnocharis* and *Philautus variabilis* constituted 66% of the index value while at Agasthyavanam, *Rana temporalis*, *Limnonectes keralensis* and *Nyctibatrachus major* contributed 82.8% of the index value (Table 2).

The distribution of amphibians in the three protected areas was found to be even (Table 4). Amphibian community at Agasthyavanam Biological Park was most evenly distributed, followed by Periyar Tiger Reserve and Peppara Wildlife Sanctuary. Estimated species richness of the 12 species reported from Peppara was 16.2 with a confidence limit of 7.8 to 24.6. Five species were found to be unique in the area. At Periyar Tiger Reserve, estimated species richness was 16.4 with five unique species. At Agasthyavanam Biological Park, the estimated species richness was 6.3 with

Table 4: Estimation of species diversity, evenness, richness and niche breadth of amphibian populations at three protected areas of Kerala

Parameters	Peppara Wildlife Sanctuary	Periyar Tiger Reserve	Agasthyavanam Biological Park
Species Diversity			
Simpson's Diversity (I-D)	0.763	0.792	0.751
Shannon-Wiener's Diversity (H')	2.665	2.830	2.064
Brillouin's Diversity (H)	2.445	2.637	1.765
Evenness measure			
Smith and Wilson's Evenness measure	0.436	0.560	0.761
Species richness			
Estimated species Richness (Jackknife Method)	16.2 + 3.27	16.4 + 2.63	6.3 + 1.33
No. of unique species	5	5	2
Niche breadth			
Levin's standardised niche breadth	0.535	0.565	0.740
No. of frequently used resources	5/8	4/5	5/6

two unique species. The ecological distribution and the relative abundance of each species were studied at all sites. The resource states based on microhabitat preference were divided into eight subgroups at Peppara Wildlife Sanctuary such as in water, on bare soil, dead leaves, rocks, logs, herbs, shrubs and trees. The distribution of amphibians within the six quadrats was found as 38 individuals/6 species in water, 20/6 on bare soil, 7/3 on dead leaves, 1/1 on rocks, 2/1 on logs, 28/2 on herbs, 23/3 on shrubs and 5/3 on trees. At Periyar Tiger Reserve, the microhabitats were divided into five subgroups, namely in water, on grass, bare soil, dead leaves and rocks. The amphibians within the 8 quadrats were distributed as 19 individuals/4 species in water, 66/7 on grass, 27/6 on bare soil, 32/4 on dead leaves and 5/2 on rocks. At Agasthyavanam Biological Park, the microhabitats were divided into six subgroups such as in water, on bare soil, shrubs, sand and rocks. The distribution of amphibians within the 3 quadrats was found as 5 individuals/2 species in water, 3/1 on grass, 5/3 on bare soil, 3/3 on rocks, 1/1 on sand and 4/1 on shrubs.

Niche breadth measurement is used to find out how organisms utilise their environment. It was measured by observing the distribution of individuals within a set microhabitats. Table 4 gives the Levin's standardised niche breadth scores for the amphibian communities at three protected areas. Niche breadth score was found to be high in Agasthyavanam Biological Park, followed by Periyar Tiger Reserve and Peppara Wildlife Sanctuary. It indicates that habitat generalists were abundant in Agasthyavanam and Periyar since the frequently used microhabitats by amphibians were five out of six and four out of five respectively. At

Peppara, frequently used microhabitats were five out of eight, indicating the presence of habitat specialists.

Niche overlap (Horn's index) is a measure of the association of two or more species. The minimum and maximum niche overlap values are 0 and 1 respectively. A value of zero indicates no overlap and 1 indicates 100% overlap (Inger and Colwell 1977). In the present study, *Euphlyctis hexadactylus* / *Euphlyctis cyanophlyctis* and *Rhacophorus malabaricus* / *Philautus pulcherrimus* showed 100% overlap value at Peppara which indicates that they are found together more often than other species in the area (Table 5a). At Peppara, among the 12 species recorded, *Rana temporalis* was found sharing the microhabitat with nine other species, with varying degrees of overlap. This was followed by *Limnonectes keralensis* and *Nyctibatrachus minor* with 8 species. *Philautus pulcherrimus*, *Polypedates pseudocruciger* and *Rhacophorus malabaricus* were found to be the least associated, their association for the microhabitat being limited to two species.

At Periyar Wildlife Sanctuary, *Rana curtipes* / *Limnonectes limnocharis* and *Euphlyctis cyanophlyctis* / *Nyctibatrachus major* were found to be more associated (Table 5b). Here *Rana temporalis* was found to share the microhabitat with all the other species, with varying degrees of overlap followed by *Limnonectes nilagirica*, *Microhyla ornata* and *Bufo melanostictus* with eight species. *Micrixalus fuscus* was the least associated species, its association for the microhabitat being limited to one species.

At Agasthyavanam Biological Park, 100% overlap was not found between any of the five species recorded. However, the maximum overlap was found between *Limnonectes*

Table 5a: Niche overlap of amphibians at Peppara Wildlife Sanctuary (Horn's index)

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	0.000	0.000	0.878	0.925	0.000	0.612	0.000	0.000	0.000	0.000	0.146
2	0.000	1.000	1.000	0.242	0.000	0.862	0.689	0.000	0.000	0.000	0.000	0.581
3	0.000	1.000	1.000	0.242	0.000	0.862	0.689	0.000	0.000	0.000	0.000	0.581
4	0.878	0.242	0.242	1.000	0.948	0.222	0.629	0.000	0.000	0.000	0.000	0.240
5	0.925	0.000	0.000	0.948	1.000	0.000	0.000	0.451	0.000	0.000	0.000	0.065
6	0.000	0.862	0.862	0.222	0.000	1.000	0.607	0.000	0.000	0.000	0.000	0.517
7	0.612	0.689	0.689	0.629	0.451	0.607	1.000	0.000	0.000	0.000	0.000	0.517
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.311	0.378	0.311	0.621
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.311	1.000	0.000	1.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.378	0.000	1.000	0.000	0.451
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.311	1.000	0.000	1.000	0.000
12	0.146	0.581	0.581	0.240	0.065	0.517	0.580	0.621	0.000	0.451	0.000	1.000

1. *Bufo melanostictus*, 2. *Euphlyctis cyanophlyctis*, 3. *E. hexadactylus*, 4. *Limnonectes keralensis*, 5. *L. limnocharis*, 6. *Nyctibatrachus major*, 7. *N. minor*, 8. *Philautus variabilis*, 9. *P. pulcherrimus*, 10. *Polypedates pseudocruciger*, 11. *Rhacophorus malabaricus*, 12. *Rana temporalis*

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Table 5b: Niche overlap of amphibians at Periyar Wildlife Sanctuary (Horn's index)

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	0.572	0.418	0.904	0.572	0.847	0.693	0.205	0.311	0.768	0.205	0.059
2	0.572	1.000	0.000	0.764	1.000	0.809	0.809	0.000	0.000	0.541	0.000	0.000
3	0.418	0.000	1.000	0.338	0.000	0.000	0.459	0.541	0.809	0.623	0.541	0.000
4	0.904	0.764	0.338	1.000	0.764	0.887	0.887	0.000	0.390	0.884	0.000	0.000
5	0.572	1.000	0.000	0.764	1.000	0.809	0.809	0.000	0.000	0.541	0.000	0.000
6	0.847	0.809	0.000	0.887	0.809	1.000	0.667	0.000	0.000	0.610	0.000	0.000
7	0.693	0.809	0.459	0.887	0.809	0.667	1.000	0.000	0.541	0.893	0.000	0.000
8	0.205	0.000	0.541	0.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000	0.000
9	0.311	0.000	0.809	0.390	0.000	0.000	0.541	0.000	1.000	0.752	0.000	0.000
10	0.768	0.541	0.623	0.884	0.541	0.610	0.893	0.000	0.752	1.000	0.000	0.000
11	0.205	0.000	0.541	0.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000	0.000
12	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

1. *Rana temporalis*, 2. *R. curtipes*, 3. *Limnonectes keralensis*, 4. *L. nilagirica*, 5. *L. limnocharis*, 6. *Philautus variabilis*, 7. *Microhyla omata*, 8. *Euphlyctis cyanophlyctis*, 9. *Polypedates pseudocruciger*, 10. *Bufo melanostictus*, 11. *Nyctibatrachus major*, 12. *Micrixalus fuscus*

Table 5c: Niche overlap of amphibians at Agasthyavanam Biological Park (Horn's index)

	1	2	3	4	5
1	1.000	0.413	0.212	0.255	0.000
2	0.413	1.000	0.925	0.168	0.000
3	0.212	0.925	1.000	0.000	0.000
4	0.255	0.168	0.000	1.000	0.764
5	0.000	0.000	0.000	0.764	1.000

1. *Rana temporalis*, 2. *Limnonectes keralensis*, 3. *Bufo melanostictus*, 4. *Nyctibatrachus major*, 5. *Micrixalus fuscus*

keralensis and *Bufo melanostictus* (Table 5c). Here, *Rana temporalis*, *Limnonectes keralensis* and *Nyctibatrachus major* were found to share the microhabitat with three other species, followed by *Bufo melanostictus* with two species and *Micrixalus fuscus* with one species.

CONCLUSION

It was evident from the present study that the amphibian communities in the three protected areas of Kerala show

greater ecological similarity (greater niche overlap) among co-existing species. Such similarities are already established for amphibian communities from tropical rain forests (Inger and Colwell 1977). It is assumed that if overlap should be greater, more species share a given variety of resources, in the absence of compensating differences in niche breadth. Resource use by ecologically more similar pairs of species is more likely to be subject to evolutionary adjustments through the combined effects of competition and environmental fluctuations (Inger and Colwell 1977). However, no such conclusion is possible in the absence of earlier studies in this region.

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